



SUBSTITUTE SPECIFICATION

AMPLIFIER INCLUDING A DOHERTY-TYPE AMPLIFIER SECTION

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to, for example, an amplifier for use by a base station device or others configuring a mobile communications system exemplified by a portable phone system or a personal handy phone system (PHS: Personal Handy phone System) and, more specifically, to the technology of downsizing a high-frequency power amplifier or others equipped with a Doherty-type amplifier with the aim of increasing the efficiency of the device.

The present invention also relates to an amplifier for use by such a base station device or others and, more specifically, to the technology of stabilizing the Doherty properties in a high-frequency power amplifier equipped with a Doherty-type amplifier with the aim of increasing the efficiency of the device.

2. Description of the Related Art

In recent years, in the wireless communications field, as is typified by a portable terminal device of a portable phone system or others, there has been a demand for downsizing the device. Such a demand for downsizing similarly exists for a

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base station device or others, and together therewith, there exists a demand for increasing the efficiency of a power amplifier that greatly influences the entire power consumption. Especially with the base station device, a high-frequency amplifier is often disposed in the vicinity of an antenna for the purpose of decreasing the cable loss between the high-frequency amplifier and the antenna. This is the reason why it is imperative that the high-frequency amplifier be made smaller in size and better in efficiency.

Generally, the high-frequency power amplifier using a semiconductor element increases in efficiency as the output increases, and the efficiency reaches its maximum in a close range of the saturation output. The level of the saturation output is dependent on the size of the semiconductor element in use. In consideration thereof, with the aim of increasing the efficiency with a low output, if a small-sized semiconductor element is used and the resulting amplifier has a low level of saturation output, the resulting output will not be sufficient at the time of high output. Conversely, if a large-sized semiconductor element is used and the resulting amplifier is highly-efficient at the time of high output, the efficiency is reduced when the output is low.

As such, it is considerably difficult to operate, with a high degree of efficiency, a single piece of amplifier at the time of both high and low outputs.

In order to solve such a problem, a so-called Doherty-type amplifier has been developed.

FIG. 5 shows an example of a standard configuration of a Doherty-type amplifier.

The Doherty-type amplifier shown in Fig. 5 is configured to include a power splitter 81 that is disposed between an input terminal 71 and an output terminal 72 to split an input signal coming from the input terminal 71. Two signal processing systems are provided to process, respectively, the signals produced as a result of the splitting. One of the signal processing systems includes a quarter wavelength line 83 connected in series to a carrier amplifier 82, which is configured as an amplifier biased to any of Classes A, AB, and B. The other signal processing system includes a quarter wavelength line 84 connected in series to a peak amplifier 85, which is configured as an amplifier biased to either Class B or C.

An exemplary operation of the Doherty-type amplifier of Fig. 5 will be described below.

When a high-frequency signal provided to the input terminal 71 is low in input power, the carrier amplifier 82 is biased to Class A, AB, or B, and outputs an amplifier signal by executing the amplifier operation irrespective of the input level of the input signal. On the other hand, the peak amplifier 85 is biased to either Class B or C, and when the instantaneous input power is low in level, the peak amplifier 85 is in the

OFF state. The direct power consumption of the peak amplifier 85 is zero (0) or sufficiently small, and thus the efficiency as a Doherty-type amplifier is also high.

Moreover, when the instantaneous input power is sufficiently high in level, the peak amplifier 85 is turned to the ON state, and the input signal directed to the peak amplifier 85 is amplified so that an output signal is generated. Thereafter, the output power from the carrier amplifier 82 is combined together with the output power from the peak amplifier 85 to produce the output from the output terminal 72, and as a result, the amplifier has a large saturation power.

Note, the Doherty-type amplifier is derived as a circuit that is a combination of an amplifier that is simply biased to Class A, AB, or B (the carrier amplifier 82), and an amplifier biased to Class B or C (the peak amplifier 85). In addition thereto, the amplifier is configured to implement the higher efficiency to a further degree by changing the dummy load impedance of the carrier amplifier 82 based on the function of the quarter wavelength line 83 provided on the output side of the carrier amplifier 82. Such a conventional device is disclosed, for example, in JP-A-2001-244751.

Although the Doherty-type amplifier is higher in efficiency in comparison with a case of in which only a high-output amplifier as above with the high saturation output is used, the circuit is complicated, which results in an

increased circuit area.

In order to solve such a problem, for example, a possibility is a technique of configuring a device substrate entirely using a material that is high in permittivity. However, material having a high permittivity is generally expensive. Also, if a ceramics substrate material of high permittivity is used, it is subject to cracking, and it is thus very difficult to manufacture the entire device with a single piece of substrate. Furthermore, compared with a low-permittivity substrate, the high-permittivity substrate requires high pattern accuracy. Therefore, increasing the permittivity of every substrate in the device actually contributes to the size reduction of the device, but this problematically results in not only increased cost of the substrate material but also an enormous cost increase due to the reduction of a manufacturing yield, accuracy control over the substrate, etc..

Furthermore, the Doherty-type amplifier is higher in efficiency in comparison with a case in which only a high-output amplifier is used as above with the high saturation output, but the circuit configuration is complicated, and influence is exerted by any physical change observed in the circuit configuration for a variety of reasons. For example, possible significant affects are a change in the electric length caused by fluctuations of the permittivity as a result of the substrate taking up moisture, or dimension change caused by shrinkage

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of the substrate due to the temperature. Such changes in the electrical properties of the substrates become a cause of hindering expected operation of the Doherty-type amplifier in consideration of the properties thereof.

To solve such problems, for example, there is a possible technique of configuring a Doherty-type amplifier entirely of a highly-stable substrate material. However, the stable material typified by a ceramic substrate or others is expensive, which results in an increased cost of the device. Moreover, if a ceramic substrate is employed, there is a possibility of cracking, and it is thus difficult to use a single substrate to cover a large area.

The present invention is proposed in consideration of the problems associated with the conventional devices described above. An object of the present invention is to provide an amplifier that can achieve size reduction in a configuration including a Doherty-type amplifier by reducing the circuit area.

A further object of the present invention is to provide an amplifier that can stabilize the properties of a Doherty-type amplifier (Doherty properties) in a configuration that includes a Doherty-type amplifier.

SUMMARY OF THE INVENTION

In order to achieve the above objects, the amplifier of the present invention takes the following configuration including a Doherty-type amplifier section (Doherty-type amplifier).

That is, the permittivity of a substrate including one or more quarter wavelength lines in the Doherty-type amplifier section is increased in comparison with the permittivity of a substrate(s) in a close range.

Accordingly, by providing one or more quarter wavelength lines in the Doherty-type amplifier section using a substrate having a relatively high permittivity, in the configuration including the Doherty-type amplifier section, the circuit area is reduced for one or more quarter wavelength lines, for example. Therefore, the circuit area can be reduced in the amplifier so that size reduction can be achieved.

Herein, the Doherty-type amplifier section may vary in type, and as an example, a configuration such as that shown in FIG. 5 is a possibility.

Further, the substrate or the permittivity of the substrate may vary in type or value.

Still further, the amplifier may vary in configuration, and an exemplary configuration includes a Doherty-type amplifier section, a high-frequency amplifier section (high-frequency amplifier), and an isolator section

(isolator).

The amplifier of the present invention includes a Doherty-type amplifier section (Doherty-type amplifier).

That is, the permittivity of a substrate employed in the Doherty-type amplifier section is made higher than the permittivity of the substrate(s) in a close range.

Accordingly, by constructing the Doherty-type amplifier section using a substrate having a relatively high permittivity, the circuit area is reduced for components that are dependent on the frequency of the Doherty-type amplifier section, for example. Therefore, the circuit area can be reduced in the amplifier so that the size reduction can be achieved.

Herein, the construction of the Doherty-type amplifier section may vary in type, and as an example, such a configuration as shown in FIG. 5 is a possibility.

Further, the substrate or the permittivity of the substrate may vary in type or value.

Still further, the amplifier may vary in configuration, and an exemplary configuration includes a Doherty-type amplifier section, a high-frequency amplifier section (high-frequency amplifier), and an isolator section (isolator).

In order to achieve the above object, the amplifier of the present invention includes a Doherty-type amplifier section (Doherty-type amplifier).

That is, a line portion forming an output circuit of a carrier amplifier included in the Doherty-type amplifier section is configured using a substrate material that is physically stable regardless of changes in the humidity and temperature.

Accordingly, by using a physically-stable substrate to construct the output circuit of the carrier amplifier that is a component of the Doherty-type amplifier section, against any environmental change of humidity or temperature, for example, the properties of the Doherty-type amplifier section (Doherty properties) can be stabilized.

As an exemplary configuration, in the amplifier that includes the Doherty-type amplifier section, the configuration can use a substrate material that is physically stable, in comparison with portions in a close range (or other portions), against either or both changes in the humidity and temperature of a substrate material of the line portion forming an output circuit of a carrier amplifier included in the Doherty-type amplifier section.

Herein, the configuration of the Doherty-type amplifier section may vary in type, and as an example, a possible configuration is shown in FIG. 5.

Further, the substrate may vary in type.

Still further, the physically-stable substrate material may vary in kind, and a possible exemplary material is one showing

a sufficiently small change of the electric length as a result of fluctuations of the permittivity caused by moisture absorption, or one showing a sufficiently small dimensional change as a result of shrinkage of the substrate due to the temperature.

Still further, used as the carrier amplifier is an amplifier that operates to amplify a signal as an amplification target irrespective of the level of the signal. The Doherty-type amplifier section is equipped with, for example, a carrier amplifier that is always put in operation when a signal as an amplification target is relatively low in level, and a peak amplifier that is put in operation only when the signal as an amplification target is relatively high in level.

The amplifier may vary in configuration, and an exemplary configuration includes a Doherty-type amplifier section, a high-frequency amplifier section (high-frequency amplifier) provided in the stage preceding the Doherty-type amplifier section (input side), and an isolator section (isolator) provided in the stage subsequent to the Doherty-type amplifier section (output side).

The amplifier of the present invention has the following configuration which includes a Doherty-type amplifier section (Doherty-type amplifier).

That is, a line portion forming an input circuit of a peak amplifier, which is included in the Doherty-type amplifier

section, is configured using a substrate material that is physically stable against either or both of changes in humidity and temperature.

Accordingly, by using a physically-stable substrate to configure the input circuit of the peak amplifier that is a component of the Doherty-type amplifier section, against any environmental change of humidity or temperature, for example, the properties of the Doherty-type amplifier section (Doherty properties) can be stabilized.

As an exemplary configuration, in the amplifier configured by including the Doherty-type amplifier section, the configuration can use a substrate material that is physically stable, in comparison with portions in a close range (or other portions), against either or both of any change observed in the humidity or the temperature for a substrate material of a line portion forming an input circuit of a peak amplifier included in the Doherty-type amplifier section.

The configuration of the Doherty-type amplifier section may vary in type, and as an example, such a possible configuration is shown in FIG. 5.

Further, the substrate may vary in type.

Still further, the physically-stable substrate material may vary in kind, and a possible exemplary material is one that has a sufficiently small change in electric length as a result of fluctuations of the permittivity caused by moisture

absorption, or one that has a sufficiently small dimensional change as a result of shrinkage of the substrate due to the temperature.

Still further, the peak amplifier may be an amplifier that operates in such a manner as to amplify a signal as an amplification target when the signal level reaches its peak. The Doherty-type amplifier section is equipped with, for example, a carrier amplifier that is always put in operation when a signal as an amplification target is relatively low in level, and a peak amplifier is put in operation only when the signal as an amplification target is relatively high in level.

The amplifier may vary in configuration, and an exemplary configuration includes a Doherty-type amplifier section, a high-frequency amplifier section (high-frequency amplifier) provided in the stage preceding the Doherty-type amplifier section (input side), and an isolator section (isolator) provided in the stage subsequent to the Doherty-type amplifier section (output side).

The amplifier of the present invention has a configuration that includes a Doherty-type amplifier section (Doherty-type amplifier).

That is, a line portion forming a combination circuit that combines an output from a carrier amplifier included in the Doherty-type amplifier section with an output from a peak amplifier is configured using a substrate material that is

physically stable against either or both of any change observed in the humidity and the temperature.

Accordingly, by using a physically-stable substrate to configure the combination circuit that is a component of the Doherty-type amplifier section, against any environmental change of humidity or temperature, for example, the properties of the Doherty-type amplifier section (Doherty properties) can be stabilized.

As an exemplary configuration, in the amplifier configured by including the Doherty-type amplifier section, the configuration can use a substrate material that is physically stable, in comparison with portions in a close range (or other portions), against either or both of changes in the humidity and the temperature for a substrate material of a line portion forming a combination circuit that combines an output from a carrier amplifier included in the Doherty-type amplifier section with an output from a peak amplifier.

The amplifier of the present invention has the configuration that includes a Doherty-type amplifier section (Doherty-type amplifier).

That is, a line portion forming an output circuit of a peak amplifier included in the Doherty-type amplifier section is configured using a substrate material that is physically stable against changes in the humidity and temperature.

Accordingly, by using a physically-stable substrate to

configure the output circuit of the peak amplifier that is a component of the Doherty-type amplifier section, against any environmental change of humidity or temperature, for example, the properties of the Doherty-type amplifier section (Doherty properties) can be stabilized.

As an exemplary configuration, in the amplifier configured by including the Doherty-type amplifier section, the configuration can use a substrate material that is physically stable, as compared with portions in a close range (or other portions), against either or both of changes of humidity and temperature for a substrate material of a line portion forming an output circuit of a peak amplifier included in the Doherty-type amplifier section.

The amplifier of the present invention includes a Doherty-type amplifier section (Doherty-type amplifier).

That is, a line portion forming an input circuit of a carrier amplifier included in the Doherty-type amplifier section is configured using a substrate material that is physically stable against either or both of changes in the humidity and temperature.

Accordingly, by using a physically-stable substrate to configure the input circuit of the carrier amplifier that is a component of the Doherty-type amplifier section, against any environmental change of humidity or temperature, for example, the properties of the Doherty-type amplifier section (Doherty

properties) can be stabilized.

As an exemplary configuration, in the amplifier configured by including the Doherty-type amplifier section, the configuration can use a substrate material that is physically stable, as compared with portions in a close range (or other portions), against either or both of any changes in humidity and temperature for a substrate material of a line portion forming an input circuit of a carrier amplifier included in the Doherty-type amplifier section.

The amplifier of the present invention includes a Doherty-type amplifier section (Doherty-type amplifier).

That is, the permittivity of a substrate configuring partially or entirely the Doherty-type amplifier section is increased in comparison with the permittivity of substrate(s) in a close range, and a line portion forming a part of the Doherty-type amplifier section is configured using a substrate material that is physically stable against either or both of any change of humidity and temperature.

Accordingly, in the configuration including the Doherty-type amplifier section, the amplifier can be reduced in circuit area so that size reduction can be achieved, and the properties of the Doherty-type amplification section (Doherty properties) can be stabilized regardless of changes in humidity or temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing an exemplary configuration of a highly-efficient high-frequency amplifier device constructed in accordance with a first example of the present invention.

FIG. 2 is a diagram showing an exemplary configuration of a substrate of a highly-efficient high-frequency amplifier device constructed in accordance with another example of the present invention.

FIG. 3 is a diagram showing an exemplary configuration of a highly-efficient high-frequency amplifier device constructed in accordance with another example of the present invention.

FIG. 4 is a diagram showing an exemplary configuration of a Doherty-type amplifier constructed in accordance with another example of the present invention.

FIG. 5 is a diagram showing an exemplary configuration of a Doherty-type amplifier.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

Embodiments of the present invention will now be described with reference to the accompanying drawings.

First of all, first to sixth examples of the present invention will be described. In the following examples, the present invention is applied to an amplifier device (a

highly-efficient high-frequency amplifier device) that implements a high degree of efficiency through amplification of high-frequency signals such as radio frequency (RF: Radio Frequency), for example. The resulting amplifier device is used in communication devices exemplified by base station devices.

More specifically, to configure a high-frequency amplifier device including a Doherty-type amplifier, substrates varying in permittivity are used for the substrate configuration of the device, and any components needed to form the Doherty-type amplifier, e.g., a quarter wavelength line, a matching circuit, a bias circuit, a splitter circuit, a combination circuit, and others, are provided by a substrate section having a high permittivity. As an exemplary possible configuration, a substrate for at least one or more quarter wavelength line portions in the Doherty-type amplifier is made to have a higher permittivity than any other substrate within a close range, or a substrate for the portion of the Doherty-type amplifier is made to have a higher permittivity than any other substrate in a close range. Such a configuration enables the suppression of increases of the area occupied by the circuits, which is often caused by the use of the Doherty-type amplifier so that a small-sized highly-efficient high-frequency amplifier device can be realized.

First Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the first example of the present invention.

FIG. 1 shows an exemplary configuration of a highly-efficient high-frequency amplifier device of this example.

The highly-efficient high-frequency amplifier device of this example is provided with, in a case 1, a substrate having a low permittivity (low-permittivity substrate) 2, and a substrate having a high permittivity (high-permittivity substrate) 3. The case 1 is equipped with a connector for inputting a high-frequency signal (high-frequency input connector) 4, and a connector for outputting the high-frequency signal (high-frequency output connector) 5. The permittivity of the low-permittivity substrate 2 is lower than that of the high-permittivity substrate 3, that is, the permittivity of the high-permittivity substrate 3 is higher than the permittivity of the low-permittivity substrate 2.

Herein, used as the low-permittivity substrate 2 is an FR-4 substrate having a relative permittivity of 4.3, for example, and used as the high-permittivity substrate 3 is a ceramic substrate having a relative permittivity of 9.8.

The high-permittivity substrate 3 is provided with a Doherty-type amplifier includes components similar to those

shown in FIG. 5, for example. The Doherty-type amplifier of this example is provided with a power splitter 21, and for one of the resulting split signals, provided are a carrier amplifier 22 configured as an amplifier that is biased to any one of Classes A, AB, and B, and a quarter wavelength line 23. For the other resulting split signal, provided are a quarter wavelength line 24, and a peak amplifier 25 configured as an amplifier that is biased to either Class B or C.

The low-permittivity substrate 2 includes two high-frequency amplifiers 11 and 12 connected in series for use as a drive stage between the high-frequency input connector 4 and the input end of the Doherty-type amplifier. The low-permittivity substrate also includes an isolator 13 between the output end of the Doherty-type amplifier and the high-frequency output connector 5.

Note that, in this example, although the low-permittivity substrate 2 is incorporated thereon with a control circuit, a power supply circuit, and other features, such features are not shown nor described in detail. Moreover, in this example, any high-frequency connection among various types of substrates is also not shown nor described in detail. It is possible to realize the connection with ease by any known technique such as a technique of using an element causing a small loss at a required frequency, e.g., a technique of establishing a connection via a chip such as chip capacitor with thought given

to the frequency characteristics, or a technique of using a gold ribbon, wire bonding, or the like.

Herein, with the Doherty-type amplifier of this example, the components 21 to 25 include the so-called quarter wavelength lines 23 and 24 as transmission lines dependent on the frequency, in other words, transmission lines dependent on the electric length. Even if some design attempts are made to change the transmission lines in layout, there are limitations on the reduction of the occupied area.

In consideration thereof, in this example, the substrate for a portion of the Doherty-type amplifier is the high-permittivity substrate 3 having a relatively high permittivity, and the substrate for other portions is the low-permittivity substrate 2, which has a relatively low permittivity. In the configuration of this example, compared with a case of using the low-permittivity substrate 2 for all of the circuits 11 to 13, and 21 to 25, for example, the configuration can be constructed with almost a half of the area. More specifically, by converting the permittivity to the electric length, the ratio of the area will be $(4.3/9.8 \times 100) = 43.9$ percent (%). As such, the highly-efficient high-frequency amplifier can be reduced in size.

As described above, with the highly-efficient high-frequency amplifier device of this example, in the configuration that includes at least one or more of the

high-frequency amplifiers 11 and/or 12 and the Doherty-type amplifier, circuits in one or more of the high-frequency amplifiers 11 and/or 12 are configured using a substrate material having a low permittivity (the low-permittivity substrate 2), and the circuits of the Doherty-type amplifier are configured using a substrate material having a higher permittivity (the high-permittivity substrate 3) compared with the substrate material (the low-permittivity substrate 2) used for one or more of the high-frequency amplifiers 11 and/or 12, and the resulting arrangements are combined. With such a configuration, realized is the high-frequency amplifier device which is higher in efficiency and smaller in size.

To be more specific, in this example, in the amplifier (in this example, the highly-efficient high-frequency amplifier device) that includes the Doherty-type amplifier sections (Doherty-type amplifiers) 21 to 25, the substrate 3 configuring one or more of the quarter wavelength lines 23 and/or 24 included in the Doherty-type amplifier sections 21 to 25 is increased in permittivity in comparison with the permittivity of the substrate(s) 2. Moreover, in this example, further, the permittivity of the substrate 3 is increased in comparison with the permittivity of the adjacent substrate(s) 2.

Accordingly, with the highly-efficient high-frequency amplifier device of this example, in the high-frequency amplifier device using the Doherty-type amplifier for

increasing the efficiency, the device can be reduced in size by using the high-permittivity substrate 3 in the circuit portions occupying the larger area such as the circuits configuring the Doherty-type amplifier. For example, in comparison with a case in which every circuit of the device is formed with the high-permittivity substrate, the resulting amplifier device can have a high degree of efficiency with a lower cost and less manufacturing effort.

As such, with the highly-efficient high-frequency amplifier device of this example, it is possible to suppress the increase of the area occupied by the circuits of the high-frequency amplifier device, which is often caused by the use of the Doherty-type amplifier so that a small-sized highly-efficient high-frequency amplifier device can be realized.

The material of the low-permittivity substrate 2 and the material of the high-permittivity substrate 3 may both vary in type.

Second Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the second example of the present invention.

The highly-efficient high-frequency amplifier device of this example includes the low-permittivity substrate 2 and the high-permittivity substrate 3, which are attached together for

use as a single piece of substrate as shown in FIG. 1, for example. Such a form implements the size reduction aspect of the highly-efficient high-frequency amplifier device.

FIG. 2 shows an exemplary configuration of a substrate of the highly-efficient high-frequency amplifier device in this example.

More specifically, Fig. 2 shows a cross section of an exemplary composite substrate that is derived by attaching together low-permittivity substrates 31, 32, and 33 (corresponding to the low-permittivity substrate 2) and a high-permittivity substrate 34 (corresponding to the high-permittivity substrate 3). Fig. 2 shows an exemplary through hole 35 and an exemplary conductor 36.

As described above, with the highly-efficient high-frequency amplifier device of this example, in the configuration that includes at least one or more of the high-frequency amplifiers 11 and/or 12, the Doherty-type amplifier, and a single piece of substrate derived by attaching together a plurality of substrate materials varying in permittivity, the Doherty-type amplifier is connected to the high-permittivity substrate portion of the substrate. This favorably realizes the high-frequency amplifier device, which is higher in efficiency and smaller in size.

Third Example

The following is a description of a highly-efficient

high-frequency amplifier device constructed in accordance with the third example of the present invention.

FIG. 3 shows an exemplary configuration of the highly-efficient high-frequency amplifier device of the third example.

In the highly-efficient high-frequency amplifier device of this example, a high-permittivity substrate 43 is provided with, not only the Doherty-type amplifier, but also with two high-frequency amplifiers 51 and 52.

More specifically, in a case 41 including a high-frequency input connector 44 and a high-frequency output connector 45, a low-permittivity substrate 42 and a high-permittivity substrate 43 are included. The high-permittivity substrate 43 includes a power splitter 53, a carrier amplifier 54, two quarter wavelength lines 55 and 56, and a peak amplifier 57, all of which configure the Doherty-type amplifier. Further, the two high-frequency amplifiers 51 and 52 are included in the stage preceding the Doherty-type amplifier, and the isolator 58 is included in the stage subsequent to the Doherty-type amplifier.

Moreover, in this example, the low-permittivity substrate 42 is configured by being incorporated thereon with a control circuit, a power supply circuit, and other features, and the high-permittivity substrate 43 is configured by being incorporated thereon with other high-frequency signal

processing portions.

Note here that, with the highly-efficient high-frequency amplifier device of this example, schematically, the configuration of the Doherty-type amplifier, the configuration of the circuit elements 41 to 45 and 51 to 58, and the entire configuration are similar to those in the highly-efficient high-frequency amplifier device shown in FIG. 1.

Since the Doherty-type amplifier requires the components dependent on the frequency, it is considered effective to configure the circuits on the high-permittivity substrate 43. Other high-frequency signal processing portions (for example, the high-frequency amplifiers 51 and 52, and the isolator 58 in this example) often include a matching circuit, a bias circuit, or others by pattern formation, and by using the high-permittivity substrate 43, the area occupied thereby can be effectively reduced. In this manner, the highly-efficient high-frequency amplifier device can be reduced in size to a further extent.

As described in the foregoing, with the highly-efficient high-frequency amplifier device of this example, in the configuration that includes at least one or more of the high-frequency amplifiers 51 and/or 52, the Doherty-type amplifier, and circuits of a power supply circuit, a control circuit, or other features accompanying one or more of these amplifiers, the high-frequency circuit portions including one

or more of the high-frequency amplifiers 51 and/or 52 and the Doherty-type amplifier are configured by a substrate material having a high permittivity (the high-permittivity substrate 43), and the accompanying power supply circuit, control circuit, or other features are configured by a substrate material having a low permittivity (the low-permittivity substrate 42) such as glass epoxy, which has a good cost performance. The above structures are combined together for use. With such a configuration, the high-frequency amplifier device can be increased in efficiency and reduced in size.

More specifically, in the amplifier configured by including the Doherty-type amplifier sections (Doherty-type amplifiers) 53 to 57, the substrate 43 including one or more of the quarter wavelength lines 55 and/or 56 in the Doherty-type amplifier sections 53 to 57 is increased in permittivity compared with the permittivity of the substrate 42. Moreover, in this example, further, the permittivity of the substrate 43, including entirely the Doherty-type amplifier sections 53 to 57, is increased in comparison with the permittivity of the substrate 42 which is disposed close to the substrate 43.

Fourth Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the fourth example of the present invention.

With the highly-efficient high-frequency amplifier

device of the fourth example, the device shown in FIG. 3 has the low-permittivity substrate 42 and the high-permittivity substrate 43 attached together for use as a single piece of substrate. More specifically, for example, the substrate is configured similarly to the one shown in FIG. 2. With such a construction, the highly-efficient high-frequency amplifier device can be reduced in size.

As described in the foregoing, the highly-efficient high-frequency amplifier device includes at least one or more of the high-frequency amplifiers 51 and/or 52, the Doherty-type amplifier, circuits of a power supply circuit, a control circuit, or other associated features accompanying one or more of these amplifiers, and a single piece of substrate formed by attaching together a plurality of substrate materials varying in permittivity. The high-frequency circuit portions, including one or more of the high-frequency amplifiers 51 and/or 52 and the Doherty-type amplifier, are configured by a substrate material having a high permittivity (the high-permittivity substrate 43). With such a configuration, the high-frequency amplifier device can be increased in efficiency and reduced in size.

Fifth Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the fifth example of the present invention.

With the highly-efficient high-frequency amplifier device of this example, the portions up to the power splitter circuit of the Doherty-type amplifier are configured by the low-permittivity substrate, and in the example of FIG. 1, for example, components configured by the low-permittivity substrate 2 are the two high-frequency amplifiers 11 and 12 for use as a drive stage, the power splitter 21, and the quarter wavelength line 24. The power combination circuit portion of the Doherty-type amplifier is configured by the high-permittivity substrate, and in the example of FIG. 1, for example, the combination circuit portion including the quarter wavelength line 23 (for example, the carrier amplifier 22, the quarter wavelength line 23, and the peak amplifier 25) is configured by the high-permittivity substrate 3.

As described in the foregoing, in the highly-efficient high-frequency amplifier device of this example, in the configuration including at least one or more of the high-frequency amplifiers 11 and/or 12 and the Doherty-type amplifier, the substrate material having a low permittivity (the low-permittivity substrate 2) is used to configure the power splitter circuit of one or more of the high-frequency amplifiers 11 and/or 12 and the Doherty-type amplifier. The combination circuit portion of the Doherty-type amplifier is configured by the substrate material having a higher permittivity (the high-permittivity substrate 3) compared with

the substrate material (the low-permittivity substrate 2) used for the power splitter circuit of one or more of the high-frequency amplifiers 11 and/or 12 and the Doherty-type amplifier. These configurations are combined together for use. The resulting configuration enables the high-frequency amplifier device to be increased in efficiency and reduced in size.

More specifically, in this example, in the amplifier configured by including the Doherty-type amplifier sections (Doherty-type amplifiers) 21 to 25, the substrate 3 configuring one or more of the quarter wavelength lines 23 and/or 24 (the quarter wavelength line 23 in this example) included in the Doherty-type amplifier sections 21 to 25 is increased in permittivity in comparison with the permittivity of the substrate(s) 2 disposed close to the substrate 3.

Sixth Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the sixth example of the present invention.

With the highly-efficient high-frequency amplifier device of the sixth example, the device configuration shown in the fifth example, for example, takes the form in which the low-permittivity substrate 2 and the high-permittivity substrate 3 are attached together for use as a single piece of substrate. More specifically, for example, the substrate

is configured similarly to the one shown in FIG. 2. With such a configuration, the highly-efficient high-frequency amplifier device can be reduced in size.

As described in the foregoing, with the highly-efficient high-frequency amplifier device of this example, a single piece of substrate is formed by attaching together the substrate material having a low permittivity (the low-permittivity substrate 2) configuring the power splitter circuits of the high-frequency amplifiers 11 and 12 and the Doherty-type amplifier to the substrate material having a high permittivity (the high-permittivity substrate 3) provided with the combination circuit portion of the Doherty-type amplifier. With such a configuration, the high-frequency amplifier device is increased in efficiency and reduced in size.

In this example, a design attempt is made to the substrate itself. Alternatively, by redesigning the quarter wavelength line, for example, the effects similar to this example can be realized (e.g., size reduction of the device). As a specific example, the quarter wavelength line may possibly take (1) the configuration in which a microstrip line is used for adjustment, (2) the configuration in which outer and inner conductors of a coaxial cable are exchanged, and (3) the configuration of using a triplate line.

The following are descriptions of the seventh to eleventh examples.

In these examples, exemplified is a case in which the present invention is applied to a Doherty-type amplifier equipped to an amplifier device (a highly-efficient high-frequency amplifier device) that can realize a high degree of efficiency through amplification of high-frequency signals such as radio frequency (RF: Radio Frequency), for example. The amplifier device is used by communications devices such as base station devices.

More specifically, to configure a high-frequency amplifier device including a Doherty-type amplifier, the transmission lines of any arbitrary portion are configured by using a substrate that is stable in spite of changes in humidity, temperature, and others, thereby reducing the degradation of properties caused by any change observed in the circumferential environment. As an exemplary configuration, a substrate for an input/output portion of a peak carrier is increased in resistance against any environmental changes so that the resulting Doherty-type amplifier is resistant against environmental changes, or a substrate for the Doherty-type amplifier may be made more stable against humidity, temperature, and others compared with the substrate(s) disposed close to the above-described substrates.

Seventh Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with

the seventh example of the present invention.

FIG. 4 shows an exemplary configuration of a Doherty-type amplifier equipped in a highly-efficient high-frequency amplifier device of this example.

The Doherty-type amplifier of this example is equipped with a power splitter 61. For one of the resulting split signals, included are a carrier amplifier 63 that is configured as an amplifier biased to any of Classes A, AB, and B, and a quarter wavelength line 64. For the other split signal, included are a quarter wavelength line 65, and a peak amplifier 66 configured as an amplifier biased to either Class B or C.

FIG. 4 shows, as components of the Doherty-type amplifier of this example, an input circuit (e.g., input line) 62 for the carrier amplifier 63, an output circuit (e.g., output line) 67 for the peak amplifier 66, and a combination circuit 68 that combines an output from the carrier amplifier 63 with an output from the peak amplifier 66.

Herein, the Doherty-type amplifier is generally configured by a substrate material of glass epoxy, which is inexpensive and easily obtained. In this example, however, the portion of the output circuit 67 of the peak amplifier 66 is configured by a substrate material that is stable. To be more specific, in this example, used as the substrate material for the portion of the output circuit 67 of the peak amplifier 66 is a substrate material such as ceramics, thereby implementing

the Doherty-type amplifier leading to the properties that are stable against any changes in environmental factors of humidity, temperature, and others. The resulting Doherty-type amplifier is stable in Doherty properties, and as such is applied to the highly-efficient high-frequency amplifier device.

Moreover, in this example, the highly-stable substrate material such as ceramics is used only for a necessary-minimum portion, thereby achieving the stable Doherty operation with a minimal cost increase.

Note here that, in this example, the high-frequency connection among various types of substrates is not shown nor described in detail. It is possible to realize the connection with ease by any known technique such as a technique of using an element causing a small loss at a required frequency, e.g., a technique of establishing a connection via a chip such as chip capacitor with thought given to the frequency characteristics, or a technique of using a gold ribbon, wire bonding, or other known techniques.

As described in the foregoing, with the highly-efficient high-frequency amplifier device of this example, in the configuration of including the Doherty-type amplifier, a substrate material that is physically stable against the humidity, the temperature, and other environmental factors, is used for a high-frequency line portion forming the output circuit 67 of the peak amplifier 66 that is one of the components

of the Doherty-type amplifier. This permits a reduction of the degradation of the Doherty properties caused by any property change observed in the substrate material affected by changes in the humidity, the temperature, and other environmental factors. Accordingly, degradation of the characteristics can be minimized.

As such, with the highly-efficient high-frequency amplifier device of this example, in the configuration of including the Doherty-type amplifier sections (Doherty-type amplifiers) 61 to 68, the line portion forming the output circuit 67 of the peak amplifier 66 in the Doherty-type amplifier sections 61 to 68 is constructed by using a substrate material that is physically stable against any humidity change, any temperature change, or other factors.

Accordingly, with the highly-efficient high-frequency amplifier device of this example, in the configuration of using a Doherty-type amplifier for the purpose of increasing the efficiency, for example, it becomes possible to solve the instability of the circuits forming the Doherty-type amplifier, and prevent the properties from being degraded as a result of any property change observed in the substrate as a result of the humidity, the temperature, and other factors so that the resulting amplifier device can be high in efficiency and less susceptible to changes in the surrounding environment.

Alternatively, as another exemplary configuration,

without restricting the portion for a stable substrate material to the portion of the output circuit 67 of the peak amplifier 66, further, the substrate material for a portion susceptible to the state of the substrate material may be replaced with the stable substrate material. With this being the case, the properties can be stabilized to an even further extent.

As such, as the configuration of the substrate of the Doherty-type amplifier, a plurality of substrates can be variously combined, and various other configurations will suffice.

Eighth Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the eighth example of the present invention.

In the highly-efficient high-frequency amplifier device of this example, in the configuration including a Doherty-type amplifier, a substrate material that is physically stable against the humidity, the temperature, and other environmental factors, is used for a high-frequency line portion forming the input circuit 62 of the carrier amplifier 63 that is one of the components of the Doherty-type amplifier.

This allows a reduction of the degradation of the Doherty properties caused by any property change observed in the substrate material as a result of the change of the surrounding environment relating to the humidity, the temperature, and other

factors. For example, the degradation of the characteristics can be minimized.

As such, with the highly-efficient high-frequency amplifier device of this example, in the configuration of including the Doherty-type amplifier sections (Doherty-type amplifiers) 61 to 68, the line portion forming the input circuit 62 of the carrier amplifier 63 included in the Doherty-type amplifier sections 61 to 68 is constructed by using a substrate material that is physically stable against any changes in the humidity, the temperature, and environmental factors.

Ninth Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the ninth example of the present invention.

With the highly-efficient high-frequency amplifier device of this example, in the configuration including a Doherty-type amplifier, a substrate material that is physically stable against the humidity, the temperature, and other environmental factors is used for a high-frequency line portion forming an output circuit of the carrier amplifier 63 that is one of the components of the Doherty-type amplifier. Here, used as the line forming the output circuit of the carrier amplifier 63, is an output path, e.g., the quarter wavelength line 64.

In the highly-efficient high-frequency amplifier device

of this example, it is possible to reduce degradation of the Doherty properties caused by any property changes observed in the substrate material as a result of any change in the surrounding environment relating to the humidity, the temperature, and other factors. For example, the degradation of the properties can be minimized. Furthermore, it is possible to prevent a problem of failing to achieve Doherty combination due to a phase change caused by degradation, by the humidity, the temperature, and other factors, of the substrate of the quarter wavelength line 64 in the stage subsequent to the carrier amplifier 63.

As such, with the highly-efficient high-frequency amplifier device of this example, in the configuration including the Doherty-type amplifier sections (Doherty-type amplifiers) 61 to 68, the line portion forming the output circuit (the quarter wavelength line 64) of the carrier amplifier 63 in the Doherty-type amplifier sections 61 to 68 is constructed by using a substrate material that is physically stable against any changes in the humidity, the temperature, and other factors.

Tenth Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the tenth example of the present invention.

With the highly-efficient high-frequency amplifier device of this example, in the configuration including a

Doherty-type amplifier, a substrate material that is physically stable against the humidity, the temperature, and other environmental factors is used for a high-frequency line portion forming an input circuit of the peak amplifier 66 that is one of the components of the Doherty-type amplifier. Here, a line forming the input circuit of the peak amplifier 66 is an input path, e.g., the quarter wavelength line 65.

In the highly-efficient high-frequency amplifier device of this example, it is possible to reduce the degradation of the Doherty properties caused by any property change observed in the substrate material affected by the change of the surrounding environment relating to the humidity, the temperature, and other factors. For example, the degradation of the properties can be minimized. Furthermore, it is possible to prevent a problem of failing to achieve Doherty combination due to a phase change caused by degradation, by the humidity, the temperature, and other factors, of the substrate of the quarter wavelength line 65 in the stage preceding the peak amplifier 66.

As such, with the highly-efficient high-frequency amplifier device of this example, in the configuration including the Doherty-type amplifier sections (Doherty-type amplifiers) 61 to 68, the line portion forming the input circuit (the quarter wavelength line 65) of the peak amplifier 66 in the Doherty-type amplifier sections 61 to 68 is constructed by using a substrate

material that is physically stable against changes in the humidity, the temperature, and environmental factors.

Eleventh Example

The following is a description of a highly-efficient high-frequency amplifier device constructed in accordance with the eleventh example of the present invention.

With the highly-efficient high-frequency amplifier device of this example, in the configuration including a Doherty-type amplifier, a substrate material that is physically stable against the humidity, the temperature, and other environmental factors is used for a high-frequency line portion forming a Doherty combination section that is one of the components of the Doherty-type amplifier. Here, a line forming the Doherty combination section is the combination circuit 68, for example.

Therefore, in the highly-efficient high-frequency amplifier device of this example, it is possible to reduce the degradation of the Doherty properties caused by any property change observed in the substrate material affected by the changes in the surrounding environment relating to the humidity, the temperature, and other factors. For example, the degradation of the characteristics can be minimized. Furthermore, a problem of failing to achieve Doherty combination due to a phase change caused by degradation, by the temperature or humidity, of the substrate of the Doherty combination section (the combination

circuit 68 in this example) can be prevented.

As such, with the highly-efficient high-frequency amplifier device of this example, in the configuration of including the Doherty-type amplifier sections (Doherty-type amplifiers) 61 to 68, the line portion forming the Doherty combination section (the combination circuit 68) included in the Doherty-type amplifier sections 61 to 68 is constructed by using a substrate material that is physically stable against any change observed in the humidity, the temperature, and other environmental factors.

Note that, with the highly-efficient high-frequency amplifier device of this example, in the configuration including a Doherty-type amplifier, for example, one or more of the circuit portions, i.e., the power splitter circuit to the peak amplifier 66 and the carrier amplifier 63 both being the components of the Doherty-type amplifier (e.g., the power splitter 61), the input circuit 62 of the carrier amplifier 63, the output circuit of the carrier amplifier 63 (e.g., the quarter wavelength line 64), the input circuit of the peak amplifier 66 (e.g., the quarter wavelength line 65), the output circuit 67 of the peak amplifier 66, and the combination circuit 68 for a signal from the carrier amplifier 63 and a signal from the peak amplifier 66, can be constructed using a substrate material that is physically stable against the humidity, the temperature, and other environmental factors.

Therefore, in the highly-efficient high-frequency amplifier device of this example, it is possible to reduce the degradation of the Doherty properties caused by property changes observed in the substrate material affected by changes in the surrounding environment relating to the humidity, the temperature, and other factors. For example, the degradation of the properties can be minimized.

Herein, the configuration of the amplifier of the present invention is not necessarily restricted to those described above, and various other configurations will do.

As described in the foregoing, according to the amplifier of the present invention, in the configuration of including a Doherty-type amplifier section (Doherty-type amplifier), the permittivity of a substrate configuring one or more quarter wavelength lines included in the Doherty-type amplifier section is increased in comparison with the permittivity of an adjacent substrate(s). With such a configuration, the area occupied by the circuits can be reduced so that the device can be reduced in size.

Further, according to the amplifier of the present invention, in the configuration of including a Doherty-type amplifier section (Doherty-type amplifier), the permittivity of a substrate configuring the Doherty-type amplifier section is increased in comparison with the permittivity of an adjacent substrate(s). With such a configuration, the area occupied

by the circuits can be reduced so that the device can be reduced in size.

Still further, according to the amplifier of the present invention, in the configuration of including a Doherty-type amplifier section (Doherty-type amplifier), a line portion forming an output circuit of a carrier amplifier included in the Doherty-type amplifier section is constructed by using a substrate material that is physically stable against changes in the humidity, and temperature. With such a configuration, the properties of the Doherty-type amplifier section (Doherty properties) can be stabilized against environmental changes in humidity or temperature, for example.

Still further, according to the amplifier of the present invention, in the configuration of including a Doherty-type amplifier section (Doherty-type amplifier), a line portion forming an input circuit of a peak amplifier included in the Doherty-type amplifier section is constructed by using a substrate material that is physically stable against any change in humidity, and temperature. With such a configuration, the properties of the Doherty-type amplifier section (Doherty properties) can be stabilized against any environmental changes in humidity or temperature, for example.

Still further, according to the amplifier of the present invention, in the configuration of including a Doherty-type amplifier section (Doherty-type amplifier), a line portion

forming a combination circuit included in the Doherty-type amplifier section is constructed using a substrate material that is physically stable against any change in humidity and temperature. With such a configuration, the properties of the Doherty-type amplifier section (Doherty properties) can be stabilized against any environmental change of humidity and temperature, for example.

Still further, according to the amplifier of the present invention, the permittivity of a substrate configuring partially or entirely the Doherty-type amplifier section is increased in comparison with the permittivity of an adjacent substrate(s), and a line portion forming a part of the Doherty-type amplifier section is constructed using a substrate material that is physically stable against either or both of changes in humidity, temperature, and other environmental factors. With such a configuration, the area occupied by the circuits of the amplifier can be reduced so that the device can be reduced in size, and the properties of the Doherty-type amplifier section (Doherty properties) can be stabilized against any environmental changes of humidity or temperature, for example.